

Improving Thermal Efficiency for Process Heating Equipment



By

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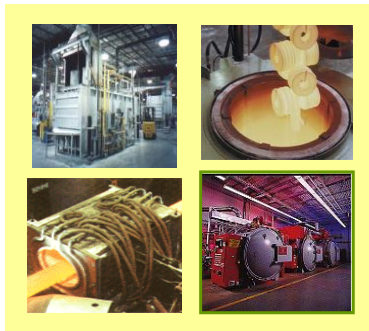
January 6, 2016

1

Process Heating Systems

What is Process Heating?

Supplying heat to materials in

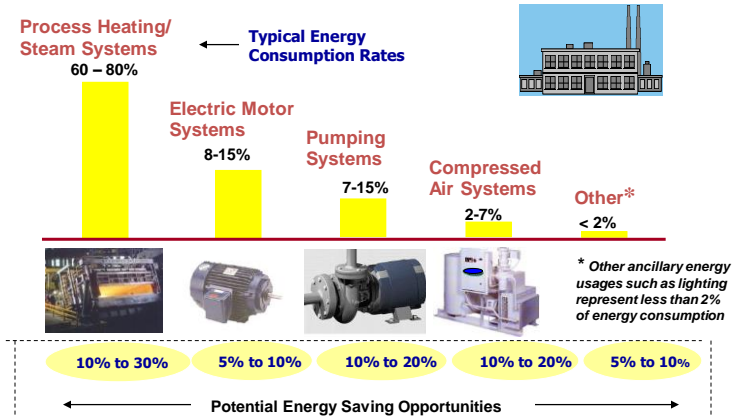


- Furnaces
- Ovens
- Heaters
- Thermal oxidizers
- Dryers
- Kilns
- Boilers
- Other heating equipment

2

Process Heating Systems

Energy Consumption and Saving Potential



3

Process Heating Systems

Process Heating Systems

Process heating systems use a variety of energy sources and methods of heating.

The three most commonly used systems in industry are:

- Fuel-fired heating systems that use fuel combustion to supply heat
- Electrically-heated systems (electrotechnologies) that use a variety of methods to generate and supply heat
- Steam-heated systems that use high-pressure steam to supply heat to the product or an intermediate medium, such as air, water, or other fluids

4

Process Heating Systems

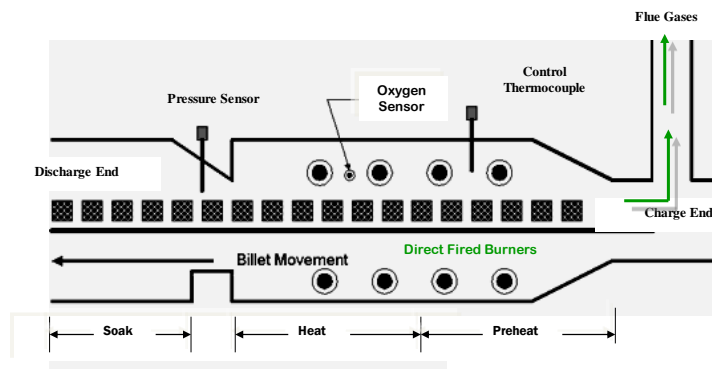
Fuel-Fired Process Heating

- In fuel-based process heating, heat is generated by the combustion of solid, liquid, or gaseous fuels, and transferred either directly or indirectly to the material
- The combustion gases can either be in contact with the material (direct heating) or be confined and thus be separated from the material (indirect heating)
- Examples of fuel-based process heating equipment include furnaces, ovens, heaters, kilns, and melters
- Approximately 65% of the process heating energy used in U.S. industry is based on fuel-fired systems

5

Process Heating Systems

Continuous Direct-Fired Furnace



The burners are fired directly in the furnace and, in most cases, the combustion products are in direct contact with the material being heated; for liquid and gas heating systems, the combustion products are in contact with the pipe or tube carrying the material.

6

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Batch Direct-Fired Furnace



The burners are fired directly or indirectly in the furnace and, in most higher temperature ($>1000^{\circ}\text{F}$) processes, the combustion products are not in direct contact with the material being heated. For lower temperature ($<800^{\circ}\text{F}$) the combustion products are in contact with the product.

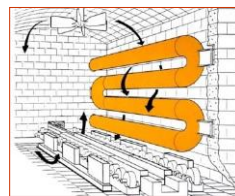
7

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Indirect Heating Systems



Indirect heating using radiant tubes for a continuous heat-treating furnace

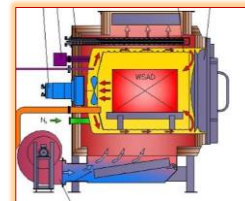


Indirect heating using radiant tubes for a batch type heat-treating furnace (Courtesy - Surface Combustion)



Radiant tubes in an indirectly heated continuous furnace

A batch type retort furnace for indirect heating of a load



8

Process Heating Systems

Process Heating Systems – Steel Industry

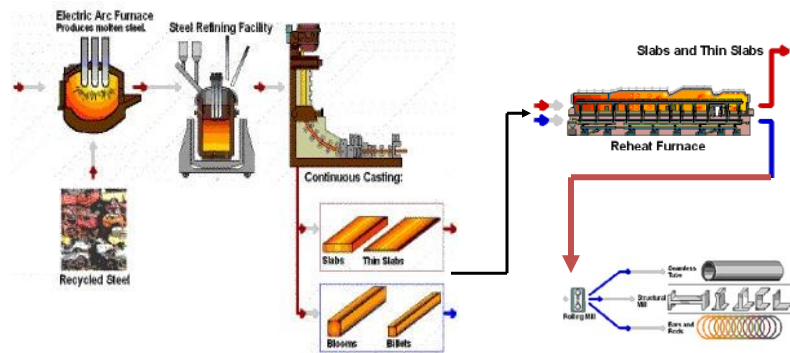


9

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Process Flow Diagram for Steel Making

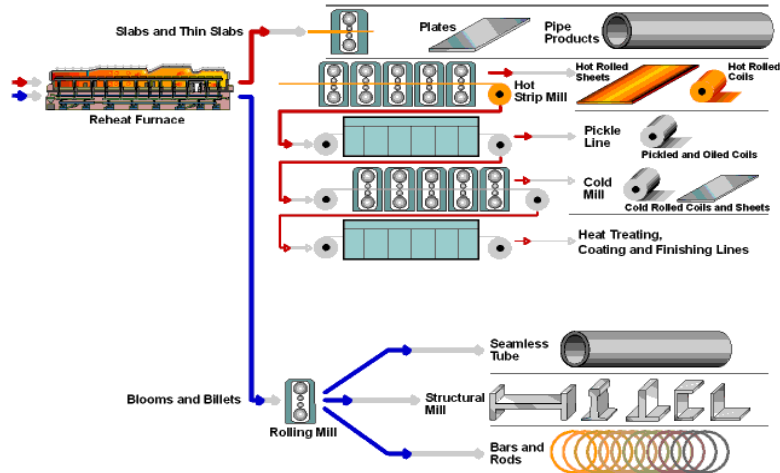
Electric Arc Furnace – Mini-Mills



10

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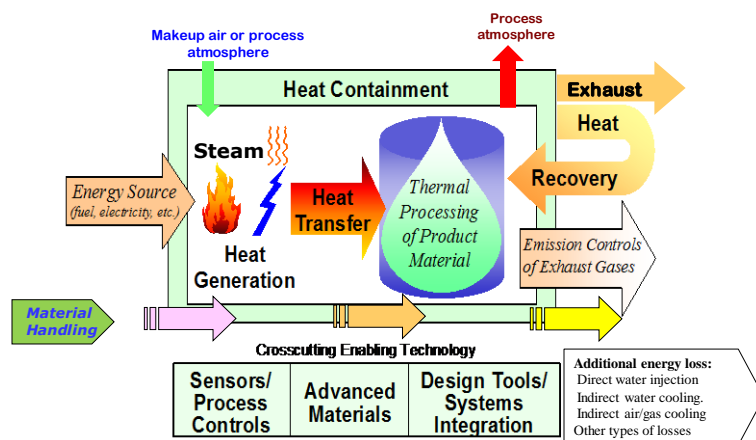
Process Flow Diagram – Rolling and Finishing



11

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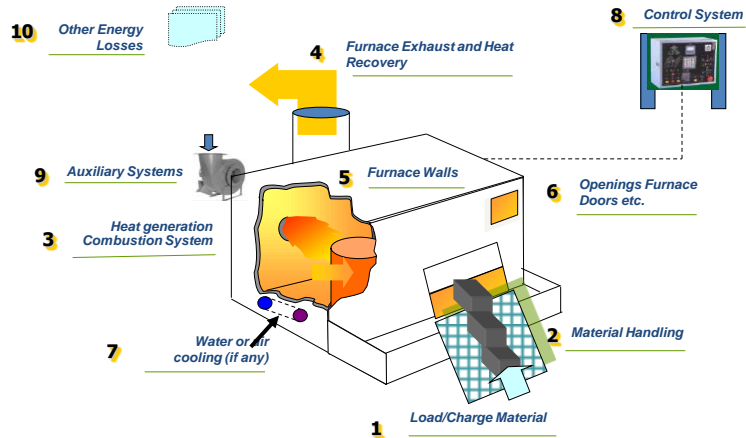
Process Heating System Components



12

Process Heating Systems

Process Heating System



13

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Steps to Improve Thermal Efficiency

- Analyze energy distribution:
 - How much energy is used and where is it going?
- Identify areas of loss or nonproductive use of energy
 - Where are the areas of heat loss?
- Estimate energy loss
 - How much energy is used or wasted as a loss?
- Identify possible energy-saving measures
 - What practical energy-saving measures can be applied to reduce or eliminate loss?
- Estimate possible energy savings
 - How much energy can be saved with application of the selected energy-saving measures?
- Analyze effects of possible energy-saving measures.
 - Are they practical? Will they have any detrimental effect on processes or other areas of operations (safety, quality)? Will they be cost-effective?
- Select appropriate energy measures and plan for application

14

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Data Collection Forms

Data Collection Forms for Process Heating Energy Assessment

No.	Area of energy use or loss	Applicability
1	Furnace information	Yes
2	Load - charge material	Yes
3	Furnace trays, conveyor, slag etc.	Yes
4	Furnace atmosphere, make up air etc.	No
5	Water air cooling - internal parts	No
6	Wall losses	Yes
7	Opening losses	Yes
8	Exhaust gases	Yes
9	Heat storage - rectangular or cylindrical furnace	No
10	Auxiliary power use	Yes

15

Process Heating Systems

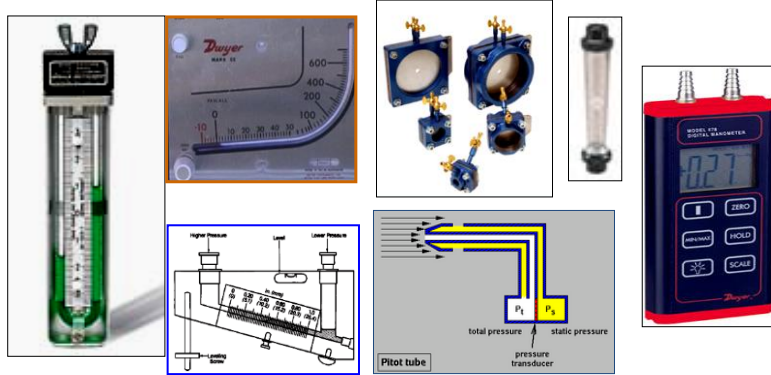
Data Collection Form – Example

Furnace - Heat Balance Analysis : Load/Charge Material				Survey Date:	
Plant Name					
Furnace					
Type of Furnace					
Type of Operations					
Use as many pages as the number of components. Fill out appropriate information for each component for current and modified operating condition of furnace					
Component Name					
FOR CONTINUOUS OPERATION			FOR BATCH OPERATION		
Description	Current condition	Modified condition	Description	Current condition	Modified condition
Type of material (Solid/Liquid/Gas)			Type of material (Solid/Liquid/Gas)		
Name of material			Name of material		
Weight of the load - Rate (lb/hr)			Weight of the load - Rate (lb/cycle)		
Initial temperature (Degree F)			Initial temperature (Degree F)		
Final temperature (Degree F) (for Solid Charge)			Final temperature (Degree F) (for Solid Charge)		
Select Name of the Liquid (SEE NOTE)			Select Name of the Liquid		
% Liquid in the load as charged (for Solid Charge)			% Liquid in the load as charged (for Solid Charge)		
% charge liquid vaporized (for Liquid Charge)			% charge liquid vaporized (for Liquid Charge)		
% Vapor in Gas Mixture (For Gas Charge)			% Vapor in Gas Mixture (For Gas Charge)		
% Liquid in the load as discharged (for Solid Charge)			% Liquid in the load as discharged (for Solid Charge)		
Vapor discharge temperature (Degree F) (for Solid Charge)			Vapor discharge temperature (Degree F) (for Solid Charge)		
Discharge temperature (Degree F) (for Liquid Charge)			Discharge temperature (Degree F) (for Liquid Charge)		
Discharge temperature (Degree F) (for Gas Charge)			Discharge temperature (Degree F) (for Gas Charge)		
% Charge (weight) reacted or Feed gas reacted			% Charge (weight) reacted or Feed gas reacted		
Type of reaction (Exothermic/Endothermic)			Type of reaction (Exothermic/Endothermic)		
Heat of reaction (Btu/lb)			Heat of reaction (Btu/lb)		
% Weight of material melted (for Solid Charge)			% Weight of material melted (for Solid Charge)		
Sp. Heat of vapor (Btu/lb. deg F) (For Gas Charge)			Sp. Heat of vapor (Btu/lb. deg F) (For Gas Charge)		
Additional heat required (Btu/hr)			Additional heat required (Btu/Cycle)		
Additional Information					

16

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Measurement Instruments (Pressure & Flow)



17

Process Heating Systems

Measurement Instruments (Temperature & Flue Gas)



18

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Data Analysis

Process Heating Assessment and Survey Tool (PHAST)

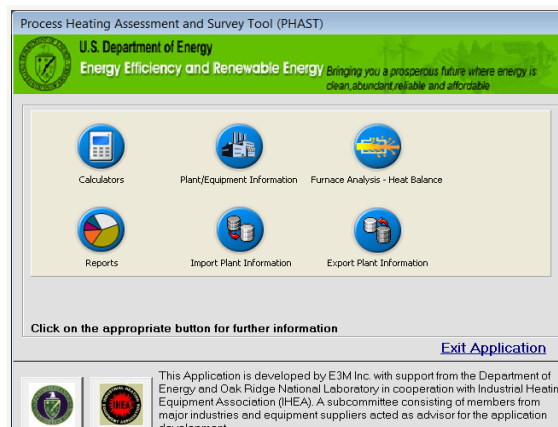
PHAST can be used to:

- Estimate annual energy use and energy cost for furnaces and boilers in a plant
- Perform detailed heat balance and energy use analysis that identifies areas of energy use and energy loss for a furnace or a boiler
- Perform “what-if” analysis for possible energy reduction and efficiency improvements through changes in operation, maintenance, and retrofits of components/systems
- Obtain information on energy-saving methods and identify additional resources

19

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Process Heating Assessment and Survey Tool (PHAST 3.0)



20

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PHAST 3.0 – Access and Requirements

PHAST version 3.0

- The tool can be downloaded from the ORNL web site.
- <http://web.ornl.gov/filedownload?ftp=e:dir=uP23XIbADwua>
- Select “Process Heating” and “Process Heating Assessment and Survey Tool (PHAST)” to download PHAST 3.0

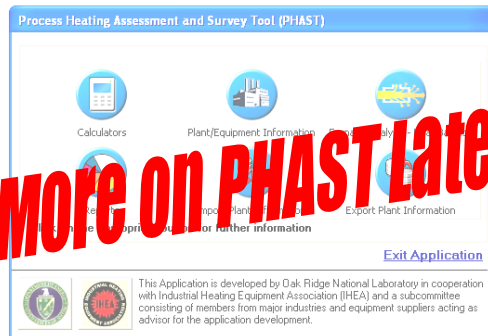
System Requirement:

- A PC running Windows 2000 /Windows XP/ Windows Vista with latest service pack.
- Microsoft Office 2000 or higher with MS Access 2000 or higher.
- Certain functions (particularly import and export) do not work with MS Access 2010.
- Acrobat PDF Reader

21

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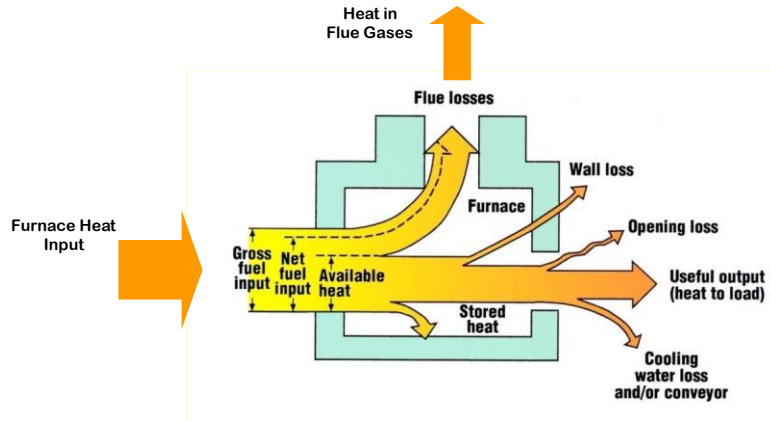
Process Heating Assessment and Survey Tool (PHAST 3.0)



22

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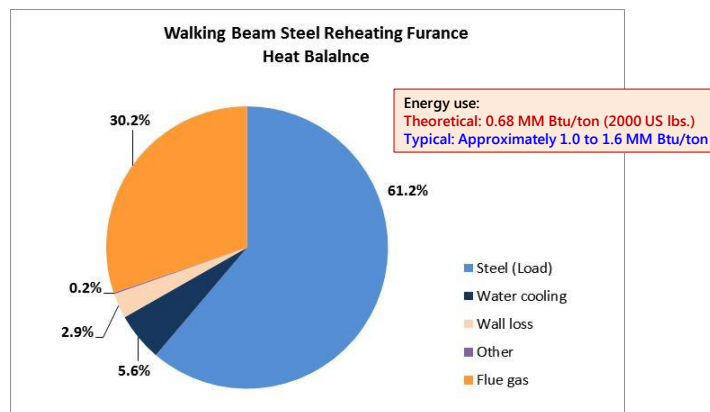
Heat Supply, Demand and Losses Fuel-Fired Heating System



23

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Typical Heat Balance for a Walking Beam Furnace EAF

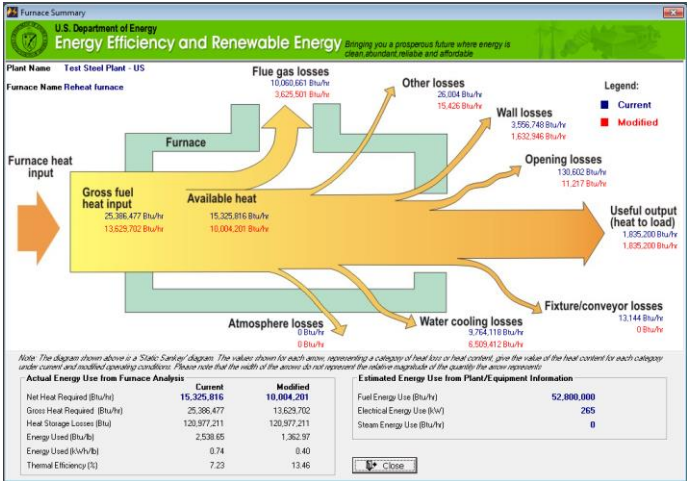


24

Process Heating Systems

Heat Supply, Demand and Losses

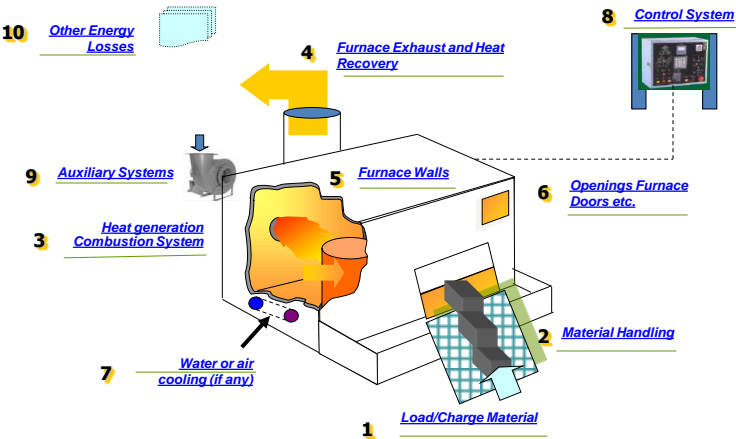
Before and After Energy Savings analysis



25

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Process Heating System Revisited



26

Process Heating Systems

Energy Saving Measures (slide 1)

1. Load - charge material

- 1 Hot charging of load - charge material (external heat source)
- 2 Reduce final load temperature
- 3 Reduce moisture content of load
- 4 Reduce load reactions (example - oxidation etc.)
- 5 Avoid partial loading

2. Material handling

- 1 Reduce weight of fixtures, trays, baskets etc.
- 2 Return hot fixture, conveyor etc.

3. Heating (combustion) system

- 1 Control of air-fuel ratio for burners
- 2 Replace constant air burners by ratio burners
- 3 Use of preheated combustion air: all or partial
- 4 Use of outdoor air during winter in closed buildings
- 5 Use of gas turbine exhaust gases for combustion air
- 6 Use of alternate fuel
- 7 Use of direct gas (fuel) firing to replace/supplement electric heating
- 8 Use of oxygen (O₂) enriched air or oxy-fuel burners for combustion



27

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Energy Saving Measures (slide 2)

4. Flue - exhaust gases loss reduction and heat recovery

- 1 Reduction of excess air or O₂ in flue (exhaust) gases
- 2 Combustion air preheating using flue gases
- 3 Preheating of load or charge material using flue gases
- 4 Use of make up air preheating - waste heat recovery
- 5 Heat cascading in lower temperature processes
- 6 Use heat from clean exhaust gases to heat water - use of direct contact heater
- 7 Use of flue gases for HVAC or other (i.e. building) air heating
- 8 Use of flue gases for fuel moisture removal (i.e. coal or bio-fuels)
- 9 Use of hot flue gases for steam generation
- 10 Use of waste heat (or steam) for absorption cooling
- 11 Electric power generation using waste heat (i.e. ORC use)
- 12 Use of regenerator system as replace or substitute recuperators

5. Wall losses

- 1 Reduce wall losses - use of lighter & better insulation for the walls
- 2 Reduce wind velocity (protection) for outside walls
- 3 Furnace operation (shut-down and start up) schedule to reduce wall heat storage
- 4 Furnace redesign to reduce hot wall surface areas



28

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Energy Saving Measures (slide 3)

6. Openings Furnace Doors etc.

- 1 Eliminate or reduce direct radiation losses from furnace openings
- 2 Minimize opening or door opening times: reduce radiation loss + leakage loss
- 3 Reduce heat loss due to exfiltration of gases from a furnace (Positive pressure)
- 4 Reduce energy loss due to air infiltration (negative pressure)
- 5 Control furnace - oven draft profile - pressure control and optimize flue size to control O₂ in flue gases at turndown conditions

7. Water or air cooling (if any)

- 1 Insulate internally water cooled or air cooled parts
- 2 Replace water cooling by air cooling where possible
- 3 Use hot water or air for absorption cooling or steam generation



29

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Energy Saving Measures (slide 4)

8. Control System

- 1 Control of air-fuel ratio (mass flow control) for burners
- 2 LEL or LFL control for ovens
- 3 Humidity control for a dryer
- 4 Control furnace/oven pressure
- 5 Model based control to assign zone set points at different operating conditions

9. Auxiliary Systems

- 1 Use of variable speed drives for motors
- 2 Use of fan and blower laws for energy savings
- 3 Use of outdoor air in colder weather for indoor installations

10. Other measures to reduce losses

- 1 Energy intensity improvement through reduction of product loss (scale, dross etc.)
- 2 Upgrade to a more efficient equipment. (replacement case)
- 3 Energy intensity improvements through productivity improvement
- 4 Sankey diagram preparation for a heat balance
- 5 CO₂ reduction with alternate energy use



30

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Range of Energy Use and Savings Potential

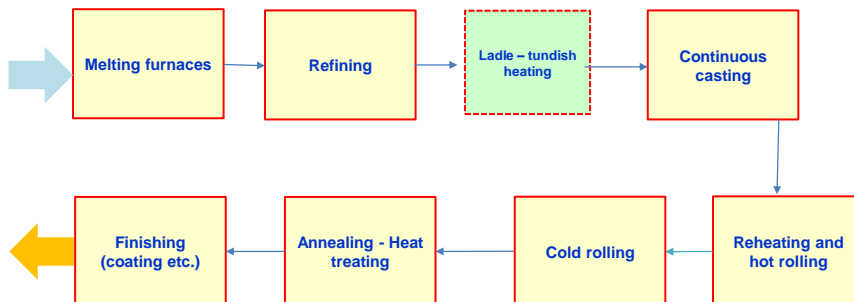
Area of energy use or loss	Range of energy use as % of the input	Range of energy savings use as % of energy use
Load/charge material	15 to 75	0 to 25
Material handling	0 to 20	0 to 50
Heat supply/heat generation (combustion system, electric, and other)	N/A	0 to 50
Furnace exhaust and heat recovery	10 to 60	0 to 50
Furnace-oven walls	2 to 15	0 to 25
Furnace openings and doors	0 to 20	0 to 100
Water or air cooling (furnace internals – if any)	0 to 15	0 to 50
Control system	N/A	0 to 10
Auxiliary systems	2 to 10	0 to 25
Other losses (i.e. atmosphere, makeup air, ex-filtration of gases etc.)	0 to 50	0 to 50

Note: The exact values depend on a number of factors and they can be obtained only by conducting a good heat balance. The US DOE tool – PHAST can be used effectively to prepare a heat balance and estimate range of values.

31

Process Heating Systems

General Material Flow and Furnaces Used at Charter Steel's Saukville, WI Plant



In processing, they receive coils (mainly from Saukville Rolling), then they clean, anneal, and ship. They may also draw before or after annealing.

32

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Plant Layout – Satellite View



33

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Reheating Furnace

Size – 118 MMBtu/hr
Fuel – Natural Gas

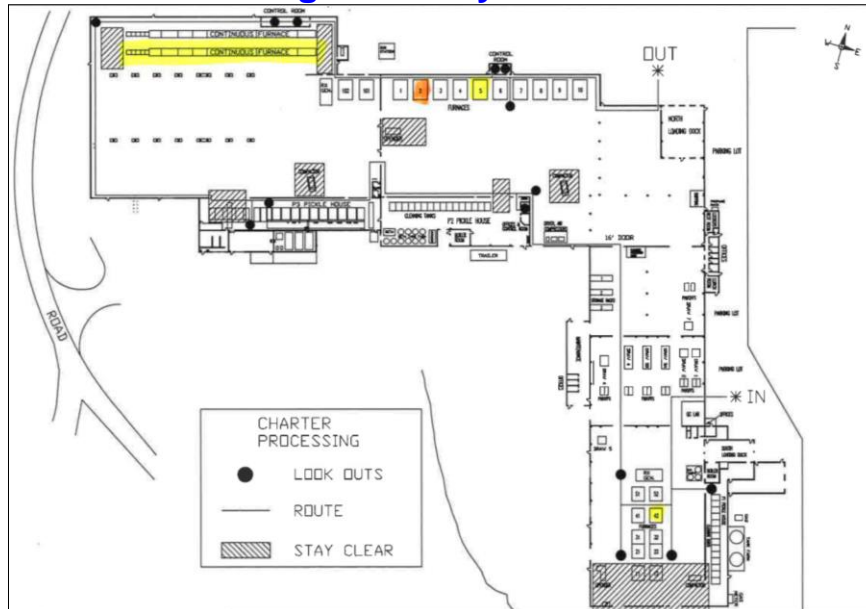


34

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Processing Plant Layout – Floor Plan



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Continuous Annealing Furnace

Furnace C2

Size – 17.6 MMBtu/hr

Fuel – Natural Gas



36

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North Annealing Furnace

Furnace 5

Fuel – Natural Gas

Size – 10.2 MMBtu/hr



37

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North Annealing Furnace

Furnace 2

Fuel – Natural Gas

Size – 10.4 MMBtu/hr



38

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South Annealing Furnace

Furnace 41

Fuel – Natural Gas

Size – 10.2 ? MMBtu/hr



39

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Demonstration

PHAST 3.0

By

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40

Process Heating Systems



SAVE THE DATE

Process Heating In-Plant Training (INPLT) Event

CHARTER STEEL

Host Site at 1658 Cold Springs Road, Saukville, WI

January 19 to 22, 2015

(Process Heating Energy Saving Assessment Jan. 19 to 21 and In-Plant Training on Jan. 22)

CONTACTS

Charter Steel Division Internal Energy Manager: Tari Emerson, (262)268-2305, emerson.t@chartersteel.com

DOE Technical Account Manager: Sachin Nimbalkar, (865.946.1548), nimbalkarsu@ornl.gov

41

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Questions and Answers



42

Process Heating Systems

Furnace Information

Sr. No.	Furnace Type	Location	Equipment #	Capacity MMBtu/hr	Operating Hours per year	Production Capacity (Tons/year)	Ports Available
1	Reheat Furnace (Billet)						
2	Continuous Annealing Furnace	Process, P3	C2	17.64	8424	39,000	not flue
3	North Annealing Box furnace (3, 4, 5, or 6)	Process, P2	5	10.20	8402.85	9271	
4	South Annealing Furnace (41, 42)	Process P1	41	10.20??	8402.85	8,667	
5	North Anneal (Salem) 2	Process, P2	2	10.40	8402.85	8341	

43

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Process Heating Systems

Furnace Information

North Anneal Furnace 2:

Rough dimensions: 19' x 18' x 20'
10.4 MMBtu/hr

North Anneal Furnace 5:

Rough dimensions: 19' x 18' x 22'
10.2 MMBtu/hr

South Anneal Furnace 42:

Rough dimensions: 17' x 15' x 15'
10.2??? MMBtu/hr

Continuous Anneal 2:

Rough dimensions: 286' L x 14' 4" W x
16' 3" H
18.51 MMBtu/hr

44

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